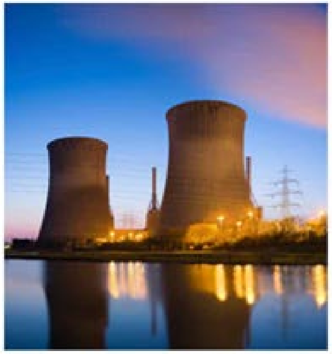
2022 Odessa Disturbance

Overview, Key Findings, and Recommendations

Informational Webinar
January 4, 2023

RELIABILITY | RESILIENCE | SECURITY

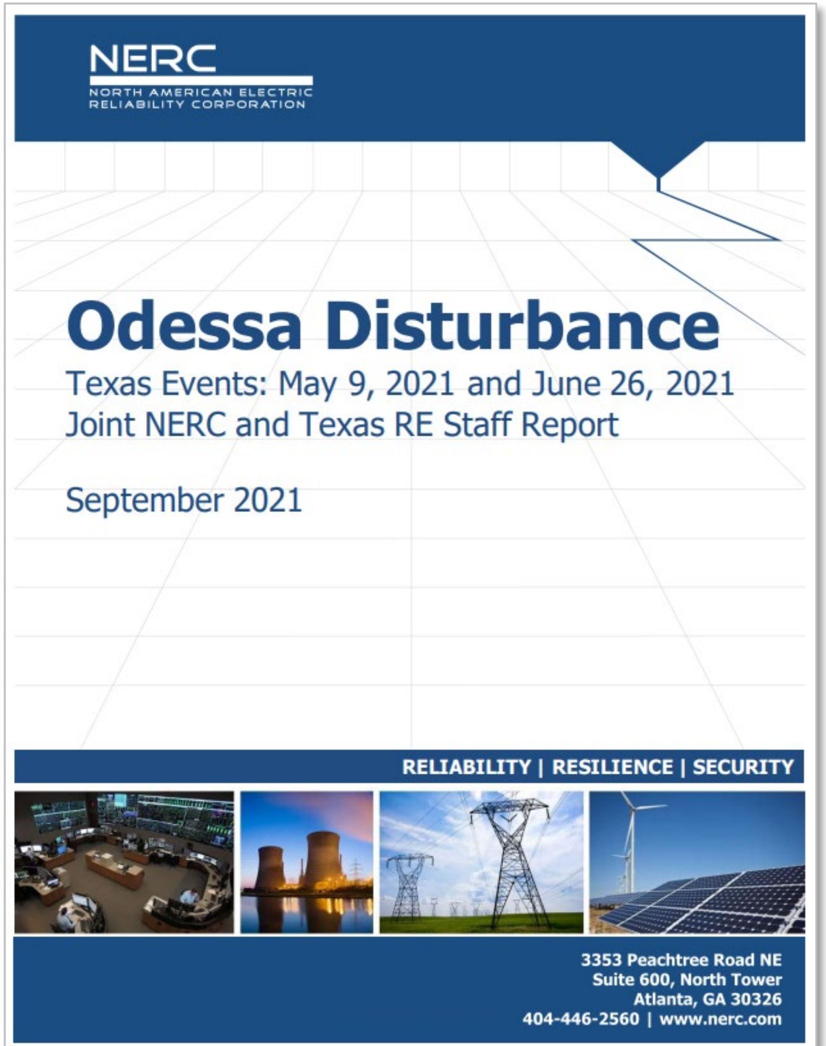
NERC Disturbance Reports

Planned Upcoming Reports:

- BESS-Related Events in California in 2022

https://www.nerc.com/pa/rrm/ea/Pages/Major-Event-Reports.aspx

Odessa Disturbance Reports



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Odessa Disturbance
Texas Events: May 9, 2021 and June 26, 2021
Joint NERC and Texas RE Staff Report

September 2021

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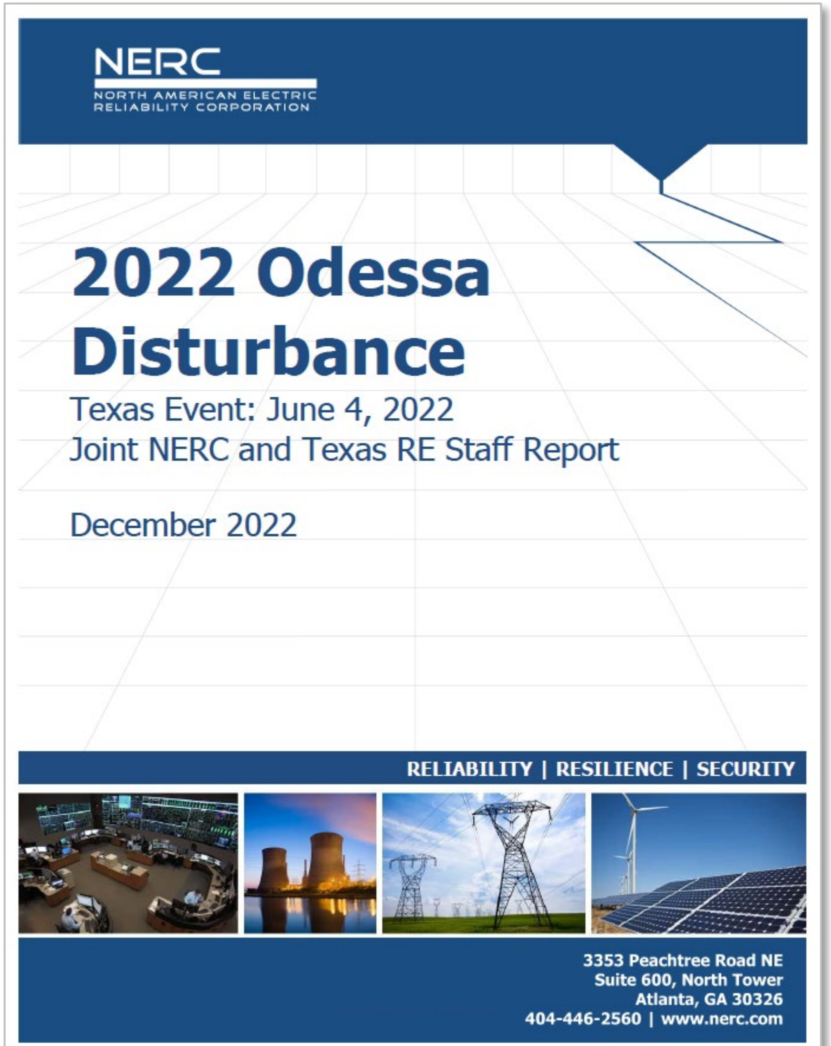
[2021 Odessa Disturbance Report]



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2022 Odessa Disturbance
Texas Event: June 4, 2022
Joint NERC and Texas RE Staff Report

December 2022

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[2022 Odessa Disturbance Report]

Introductions

Ryan Quint
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Alex Shattuck
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Matthew Lewis
Manager, NERC

Rich Bauer
Associate Principal Engineer, NERC

David Penney
Sr. Principal Engineer, Texas RE

Patrick Gravois
Lead Operations Engineer, ERCOT

Stephen Solis
Principal, ERCOT

Event Analysis Process and Event Overview

Matt Lewis, NERC
David Penney, Texas RE

Event to Disturbance Report

Categories and Subcategories for EAP Qualifying Events

Category 1: An Event that Results in One or More of the Following:

a. An unexpected outage, that is contrary to design, of three or more BES Facilities caused by a common disturbance, listed here:
   i. The outage of a combination of three or more BES Facilities (excluding successful automatic reclosing)
   ii. The outage of an entire generation station of three or more generators (aggregate generation of 500 MW to 1,999 MW); each combined-cycle unit is counted as one generator

b. Intended and controlled system separation by the proper operation of a remedial action scheme (RAS) in New Brunswick or Florida from the EI

c. Failure or misoperation of a BES RAS

d. System-wide voltage reduction of 3% or more that lasts more than 15 continuous minutes due to a BES Emergency

e. Unintended BES system separation that results in an island of 100 MW to 999 MW. This excludes BES radial connections and non-BES (distribution) level islanding

g. In ERCOT, unintended loss of generation of 1,400 MW to 1,999 MW

h. Loss of monitoring or control at a control center such that it significantly affects the entity's ability to make operating decisions for 30 continuous minutes or more. Some examples that should be considered for Event Analysis reporting include, but are not limited to, the following:
   i. Loss of operator ability to remotely monitor or control BES elements
   ii. Loss of communications from supervisory control and data acquisition (SCADA) remote terminal units (RTUs)
   iii. Unavailability of inter-control center protocol (ICCP) links, which reduces BES visibility
   iv. Loss of the ability to remotely monitor and control generating units via automatic generator control (AGC)
   v. Unacceptable state estimator (SE) or real-time contingency analysis solutions

i. A non-consequential interruption of inverter type resources aggregated to 500 MW or more not caused by a fault on its inverters, or its ac terminal equipment

j. A non-consequential interruption of a dc tie, between two separate asynchronous systems, loaded at 500 MW or more, when the outage is not caused by a fault on the dc tie, its inverters, or its ac terminal equipment

Category 2: An Event that Results in One or More of the Following:

a. Complete loss of interpersonal communication and alternative interpersonal communication capability affecting its staffed BES control center for 30 continuous minutes or more

c. Voltage excursions within a TOP's footprint equal to or greater than 10%, lasting more than 15 continuous minutes

d. Complete loss of off-site power (LOOP) to a nuclear generating station per the Nuclear Plant Interface Requirement

e. Unintended system separation that results in an island of 1,000 MW to 4,999 MW

f. Unintended loss of 300 MW or more of firm load for more than 15 minutes

g. Interconnection reliability operating limit (IROL) exceedance for time greater than T_v

Category 3: An Event that Results in One or More of the Following:

a. Unintended loss of load, generation (including inverter type resources), or dc tie to asynchronous resources of 2,000 MW or more

b. Unintended system separation that results in an island of 5,000 MW to 10,000 MW

c. Unintended system separation (without load loss) that islands Florida from the Eastern Interconnection

Category 4: An Event that Results in One or More of the Following:

a. Unintended loss of load or generation from 5,001 MW to 9,999 MW

b. Unintended system separation that results in an island of more than 10,000 MW (with the exception of Florida as described in Category 3c)

Category 5: An Event that Results in One or more of the Following

a. Unintended loss of load of 10,000 MW or more

b. Unintended loss of generation of 10,000 MW or more

EA Program

Event Analysis Process

Step 1: The registered entity assesses an event, determines the event category, and notifies the RE.

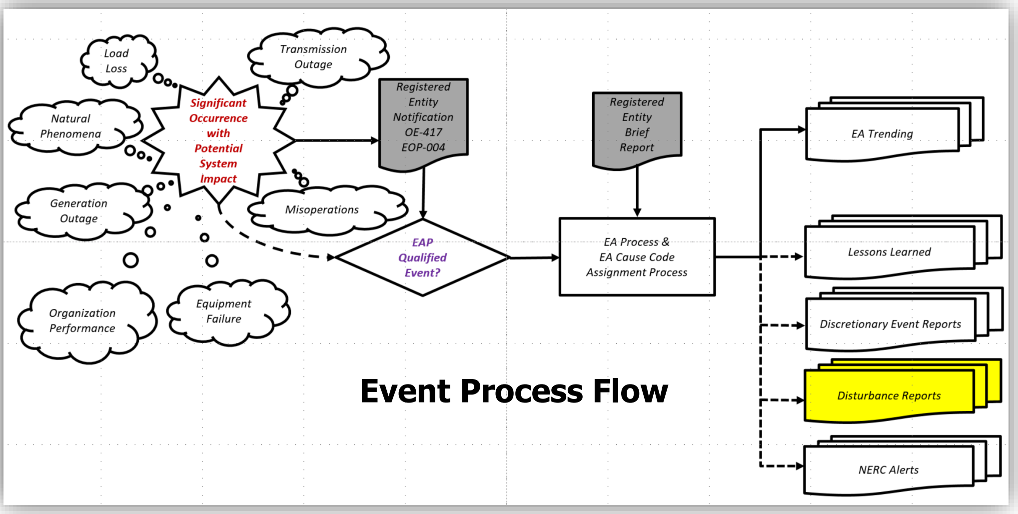
Step 2: A planning meeting or coordination call (Appendix B) is held between the registered entity and the RE when possible.

Step 3: The registered entity submits a Brief Report (Appendix C) to the RE.

Step 4: The registered entity submits an Event Analysis Report (EAR) (Appendix D) to the RE, if needed.

Step 5: Lessons learned (Appendix E) are developed and shared with industry as appropriate.

Step 6: The EAP is closed.



Major Event Reports

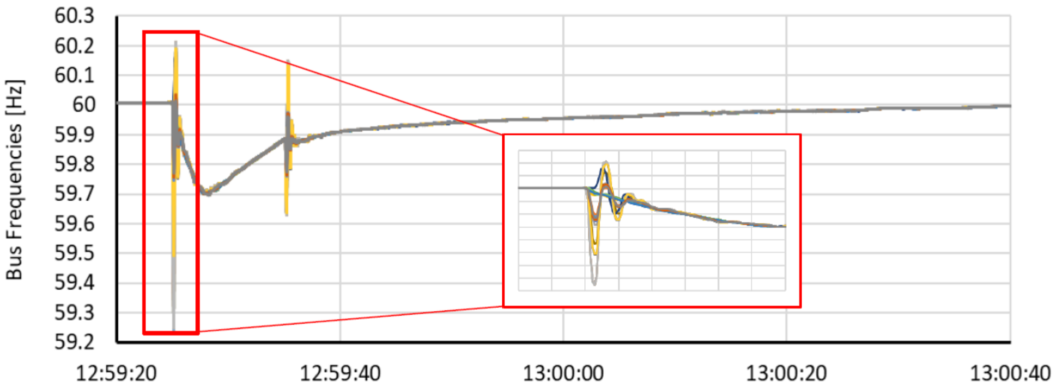
Overview of Events: June 4, 2022

- 345 kV single-line-to-ground fault at 12:59 PM CT
- Fault cleared normally in 3 cycles
- 2,555 MW loss of generation (Category 3a event)
  - 844 MW loss of synchronous generation
  - 1,711 MW loss of BPS solar PV generation
- System frequency dropped to 59.7 Hz
- 2,343 MW of responsive reserve service deployed
  - 2,442 MW available at time of event
  - About 50/50 split between load resources and generation

Table ES.1: Reductions of Output by Unit Type

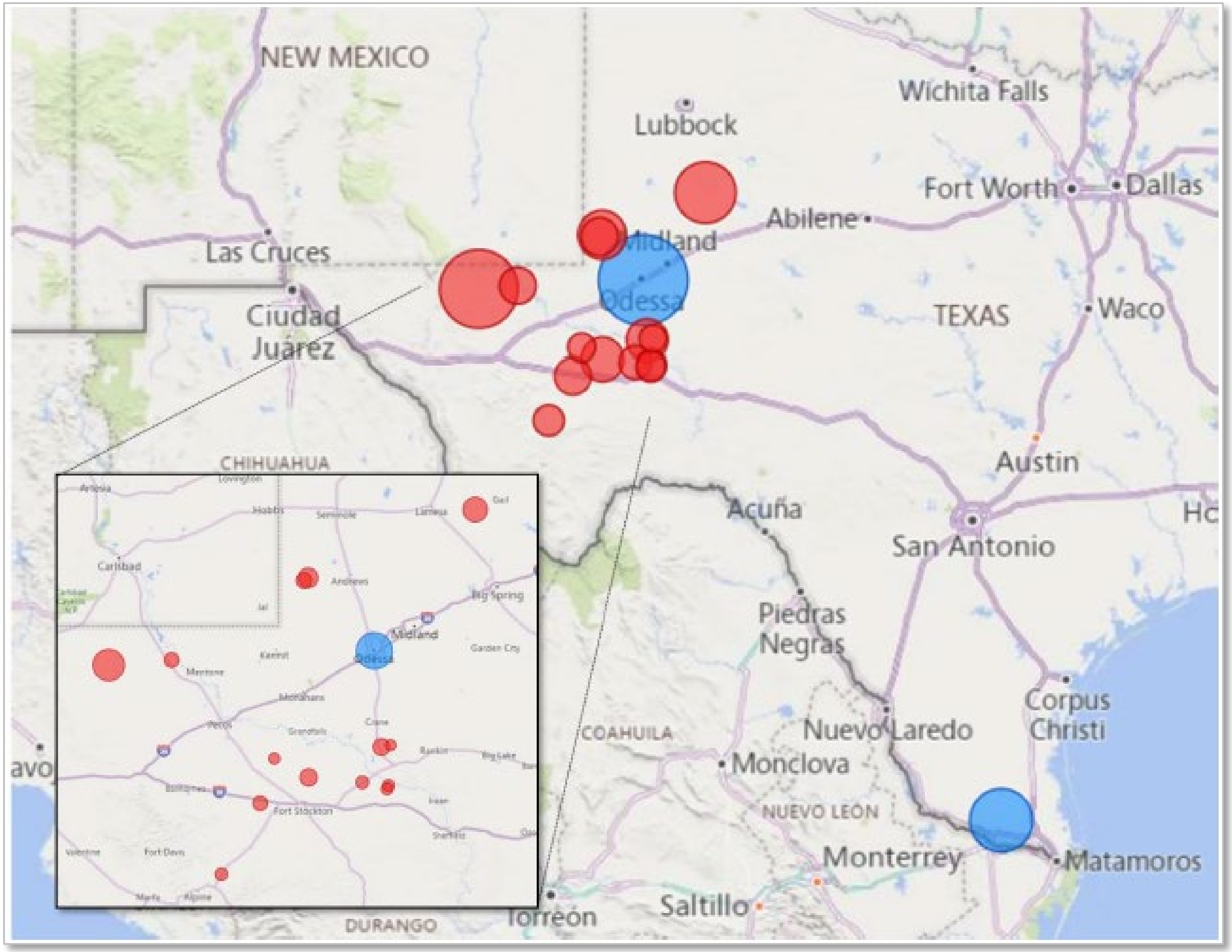
Plant Type	Reduction [MW]
Synchronous Generation Plants	844
Solar PV Plants	1,711
Total	**2,555**

PMU Frequency and Voltage



- Lowest recorded voltage of 0.714 PU on 345 kV line in the area
- Highest recorded voltage of 1.102 PU on 138 kV line
- Attempted reclose ~ 10 seconds later
- Lowest frequency of 59.7 Hz on most PMUs
- Local transient frequencies seen as low as 58.83 Hz and as high as 60.26 Hz

Fault Location and Affected Facilities



Predisturbance Operating Conditions

2021 Event

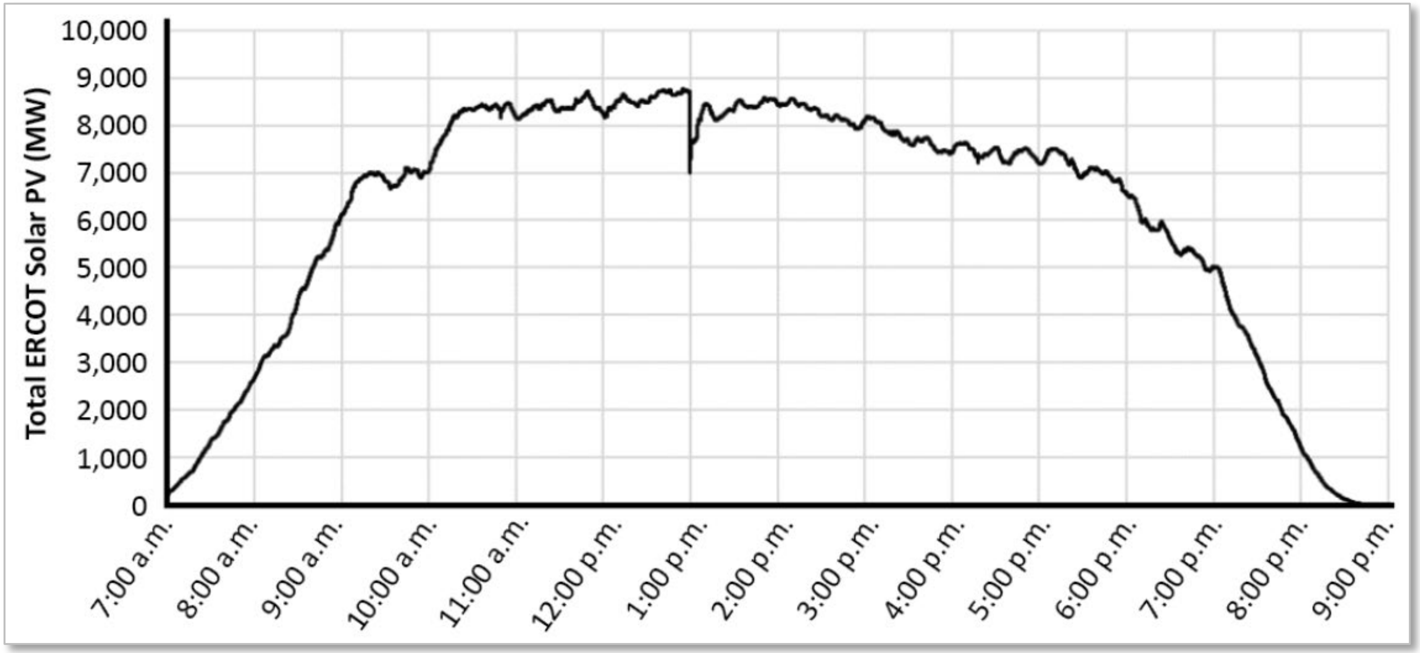
Table I.1: Predisturbance Resource Mix		
BPS Operating Characteristic	**MW**	**%**
Internal Net Demand	47,434	-
Solar PV Output	4,533	9%
Wind Output	15,952	34%
Synchronous Generation	26,383	56%

*ERCOT was importing 566 MW through dc ties

2022 Event

Table I.1: Predisturbance Resource Mix		
BPS Operating Characteristic	**MW**	**Percentage**
Internal Net Demand	55,436	-
Solar PV Output	8,740	15.8%
Wind Output	5,742	10.4%
Synchronous Generation	40,744	73.5%

*ERCOT was importing 210 MW



Loss of Synchronous Generation

- Plant near Odessa
  - Surge arrestor failure, consequential tripping
  - Misoperation of transformer differential protection due to CT saturation
  - Plant corrected protection settings to eliminate risk
  - Total loss of 535 MW (ramping over minutes down 829 MW)

- Plant in South Texas
  - Automatic voltage regulator placed in manual rather than automatic mode during excitation system upgrade in 2020 – incorrect settings
  - Plant distributed control system logic also incorrectly misinformed operator
  - Issue corrected by placing AVR in automatic mode
  - Total loss of 309 MW (over 450 miles away)

Growing Solar PV Portfolio

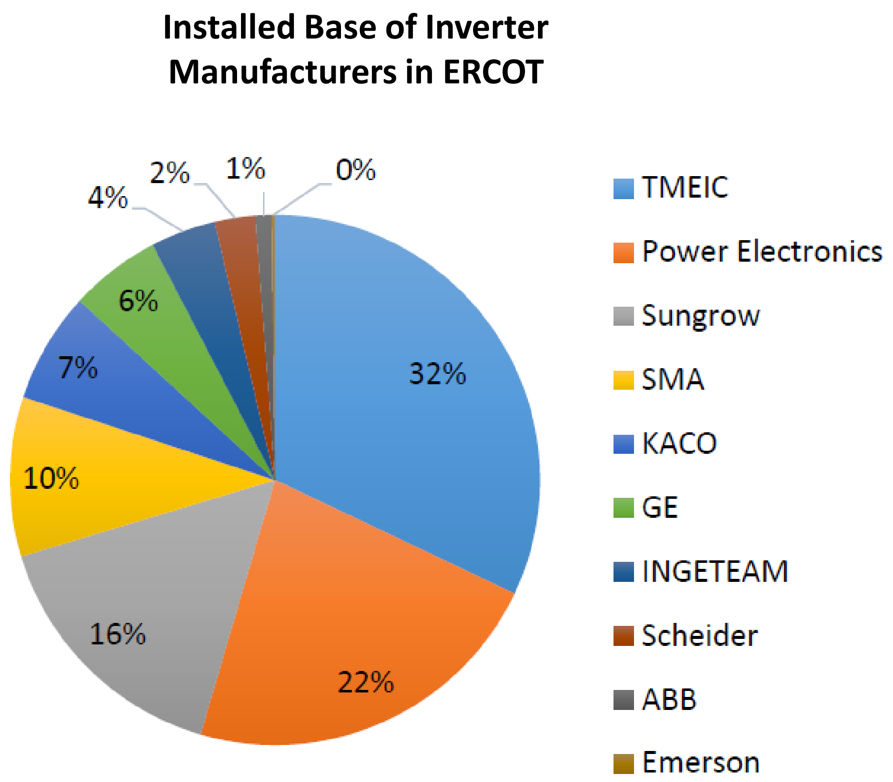
- Magnitude of reduction highlights importance of ensuring all BPS-connected inverter-based resources are operating in a manner that ensures reliable operation of the BPS

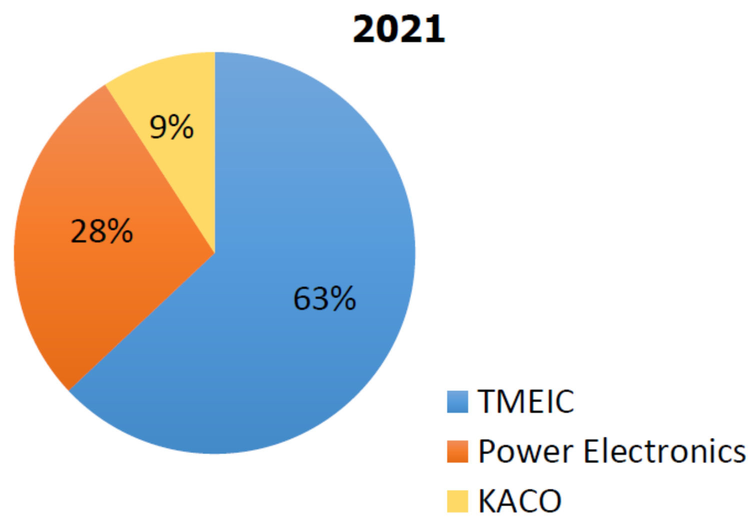
- **Time of Event:** ~~7,200~~ 8,660 MW solar PV resources in ERCOT
  - Additional ~~790~~ 3,010 MW in commissioning process
- **Near Future:** ~~25,000~~ 28,850 MW solar PV resources with signed interconnection agreements in ERCOT generation interconnection queue between now and 2023

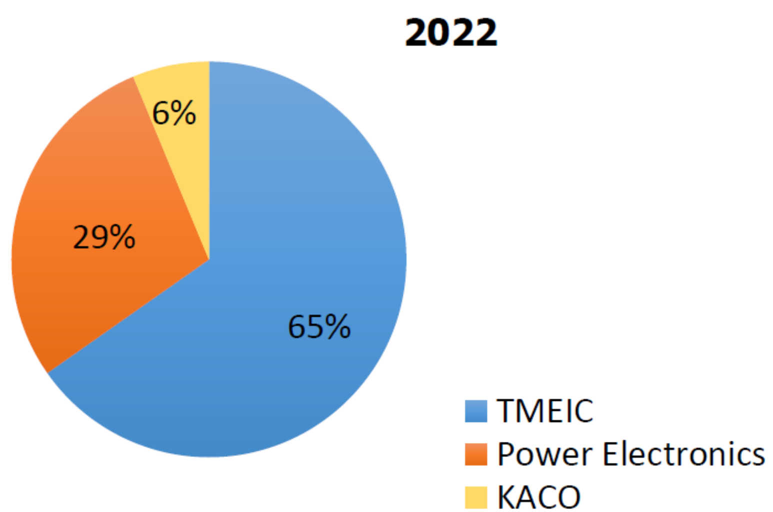
Review of Solar PV Causes of Reduction

Ryan Quint, NERC
Patrick Gravois, ERCOT

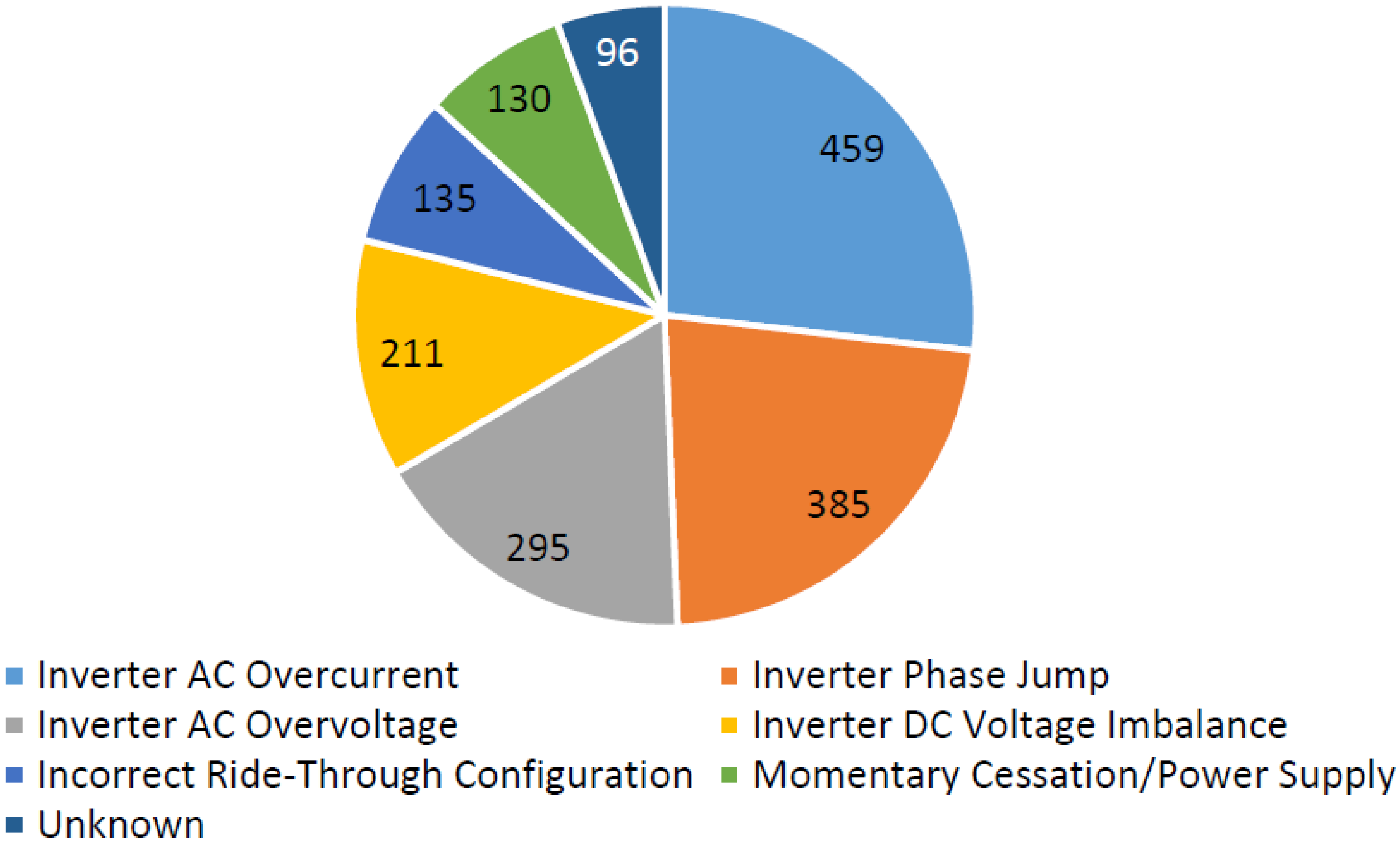
Affected Solar PV Inverter OEMs







Cause of Solar PV Reduction



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Cause of Solar PV Reduction

Table 1.1: Causes of Solar PV Active Power Reductions

Cause of Reduction	Odessa 2021 Reduction [MW]	Odessa 2022 Reduction [MW]
Inverter Instantaneous AC Overcurrent	–	459
Passive Anti-Islanding (Phase Jump)	–	385
Inverter Instantaneous AC Overvoltage	269	295
Inverter DC Bus Voltage Unbalance	–	211
Feeder Underfrequency	21	148*
Unknown/Misc.	51	96
Incorrect Ride-Through Configuration	–	135
Plant Controller Interactions	–	146
Momentary Cessation	153	130**
Inverter Overfrequency	–	–
PLL Loss of Synchronism	389	–
Feeder AC Overvoltage	147	–
Inverter Underfrequency	48	–
Not Analyzed	34	–

* In addition to inverter-level tripping (not included in total tripping calculation.)
** Power supply failure

Comparison Between Events

Table 2.1: Causes of Tripping and Changes Made Between Events

Plant	Odessa 2021 Cause of Reduction	Changes Made to Affected Plant	Odessa 2022 Cause of Reduction
Plant A	Unknown	None	Not involved
Plant B	PLL loss of synchronism tripping	PLL loss of synchronism protection function disabled in all inverters	Passive anti-islanding (voltage phase jump)
Plant C and Plant D	Inverter instantaneous ac overvoltage tripping	None; EMT modeling to explore decreasing reactive power support (K-factor setting) in progress during 2022 Odessa Disturbance	Passive anti-islanding (voltage phase jump)
Plant E	Feeder instantaneous underfrequency tripping	None by 2022 Odessa Disturbance; has since increased feeder relay frequency measurement window to 10 cycles	Inverter ac overvoltage
Plant F	Inverter instantaneous underfrequency tripping	None by 2022 Odessa Disturbance; has since increased frequency measurement window to 2 seconds	Unknown (Inverter logs overwritten)
Plant G and Plant H	PLL loss of synchronism tripping	PLL loss of synchronism protection function disabled in all inverters	Not involved
Plant I and Plant J	Inverter instantaneous ac overvoltage tripping	None by 2022 Odessa Disturbance; EMT modeling for decreasing K-factor in progress during 2022 Odessa Disturbance; have since decreased reactive power support (K-factor setting) from 2 to 1 and increased overvoltage threshold from 1.25 pu to 1.4 pu	Passive anti-islanding (voltage phase jump)
Plant K and Plant L	Momentary cessation with slow recovery due to plant controller interactions	Replaced plant-level controller and implemented logic to speed recovery	Momentary cessation/loss of inverter auxiliary power
Plant M	Feeder instantaneous ac overvoltage tripping	Disabled all feeder breaker overvoltage protection	Low voltage ride-through mode disabled; slow inverter ramp rate
Plant N and Plant O	Unknown	None	Unknown

Layered inverter protections

No mitigations deployed between events

Change management issues

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Review of Affected Solar Plants

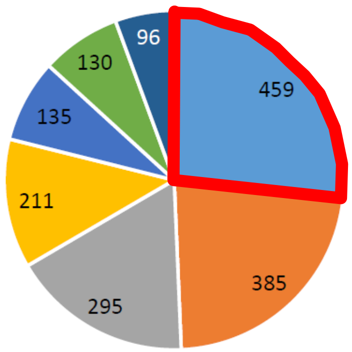
Table A.1: Review of Solar PV Facilities

Facility ID	Capacity [MW]	Reduction [MW]	POI Voltage [kV]	In-Service Date	Cause of Reduction
Plant B	152	133	138	June 2020	Inverter phase jump (passive anti-islanding) tripping.
Plant C	126	56	345	November 2020	Inverter phase jump (passive anti-islanding) tripping.
Plant E	162	159	138	May 2021	Inverter ac overvoltage tripping.
Plant U	143.5	136	138	August 2021	Inverter ac overvoltage tripping; feeder underfrequency tripping.
Plant F	50	46	69	September 2017	Unknown.
Plants I & J	304	196	345	June 2020	Inverter phase jump (passive anti-islanding) tripping.
Plant V	253	106	345	July 2021	Inverter dc voltage imbalance tripping.
Plants K & L	157.5	130	138	September 2016	Momentary cessation/inverter power supply failure.
Plant M	155	146	138	March 2018	Inverter dc voltage imbalance tripping; incorrect inverter ride through configuration.
Plant N	110	35	138	March 2017	Unknown.
Plant O	50	15	138	November 2016	Unknown.
Plant P	157.5	10	138	August 2017	Inverter ac overcurrent tripping.
Plant Q	255	12	138	December 2020	Inverter ac overcurrent tripping.
Plant R	268	261	138	June 2021	Inverter ac overcurrent tripping.
Plant S	100	94	138	December 2019	Inverter dc voltage imbalance tripping.
Plant T	187	176	138	September 2021	Inverter ac overcurrent tripping; feeder underfrequency tripping.
TOTAL		**1,711**			

* Naming convention of facilities is a continuation of the 2021 Odessa Disturbance; therefore, plant numbering is not necessarily alphanumeric but does match the labeling used in the 2021 Odessa Disturbance.

* Denotes plants that went into commercial operation in late 2020 onward

Inverter Instantaneous AC Overcurrent Protection



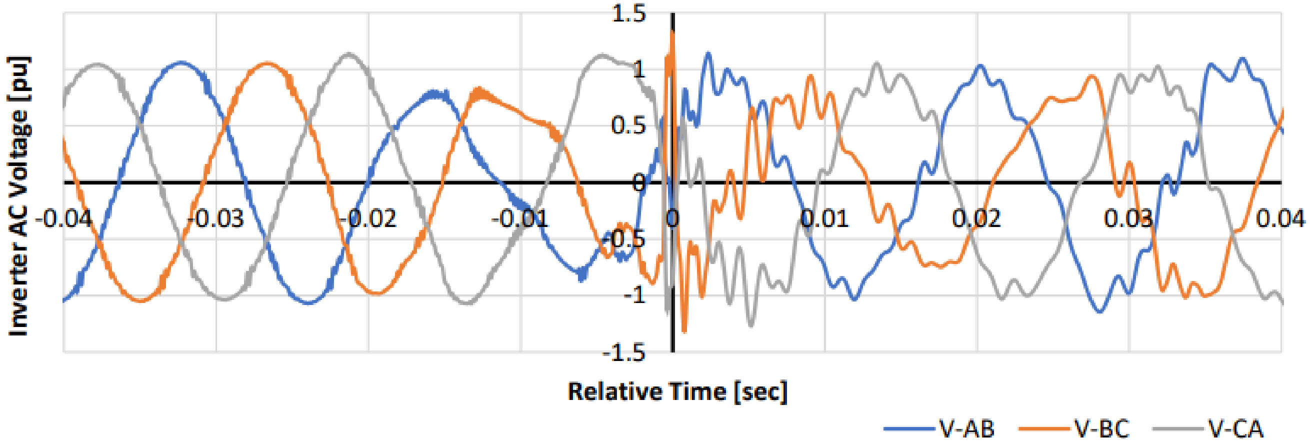


Figure 1.3: Inverter-Level High Speed Oscillography Voltage Data

Trip levels:

- **1.4 pu (minor)**
- **1.5 pu (major)**
- **Instantaneous (0.2 ms)**

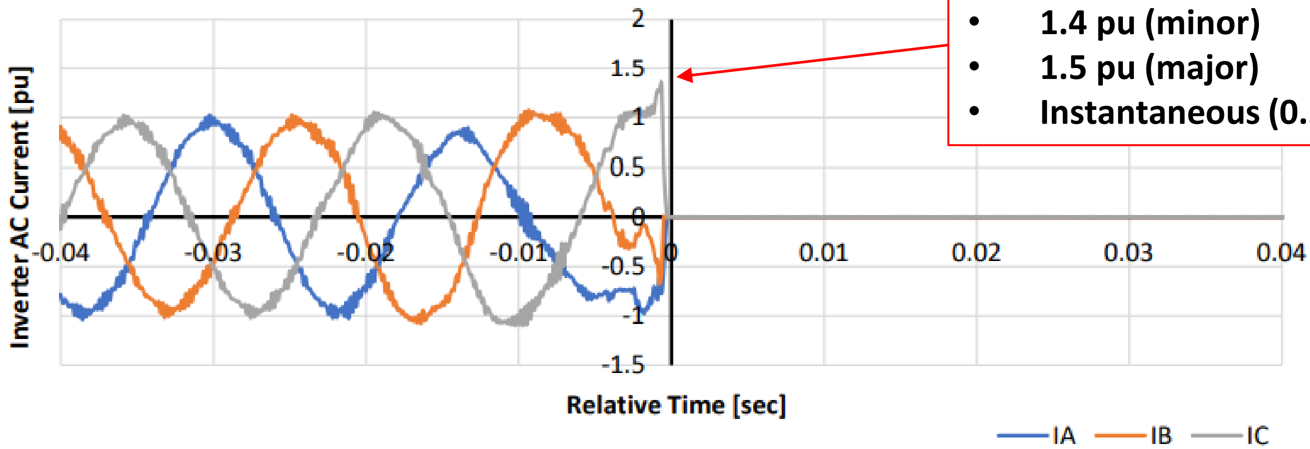
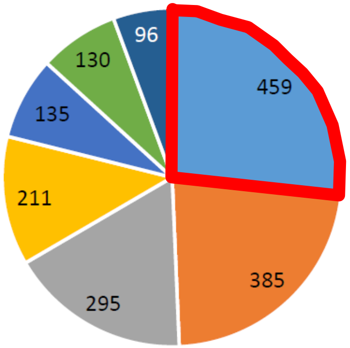


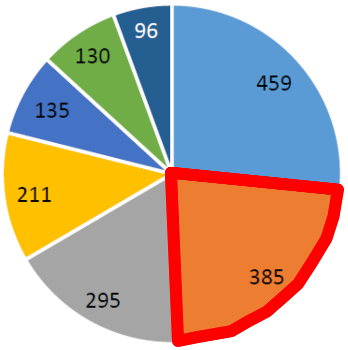
Figure 1.4: Inverter-Level High Speed Oscillography Current Data

Inverter Instantaneous AC Overcurrent Protection



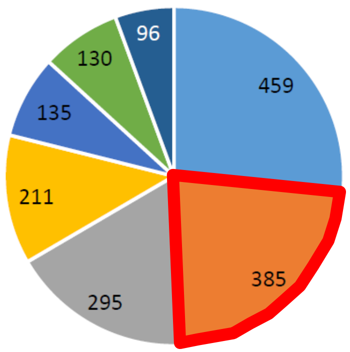
- Observed across three inverter manufacturers; tripping primarily one large manufacturer
- Caused by inverter controls during on-fault conditions
  - Inverter drives ac current over ratings and trips during fault
- Software algorithm developed to mitigate tripping
  - Modifies inverter switching logic during faults
  - Testing confirmed with hardware-in-the-loop testbed
- Requires inverter personnel on-site to modify inverter firmware and parameters
- Changes only being made to facilities that request the update
- Changes to EMT model will be needed to reflect updated inverter control strategy

Inverter Phase Jump Protection



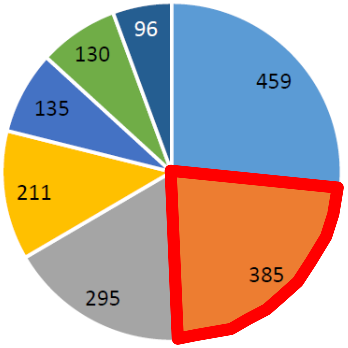
- Largest reduction in 2021 Odessa Disturbance = "PLL loss of synchronism tripping"
  - NERC guidance years before highlighted that changes in grid phase should not trip inverters
  - Inverter OEM determined it to be redundant to other protections; now disables PLL loss of synch protection by default
  - ERCOT has confirmed that updates have been made at all BPS-connected facilities of this manufacturer in their footprint; however, this protection may still be enabled in other existing inverters.
  - GOs will need to request disabling the protection to ensure ride-through during BPS faults.

Inverter Phase Jump Protection



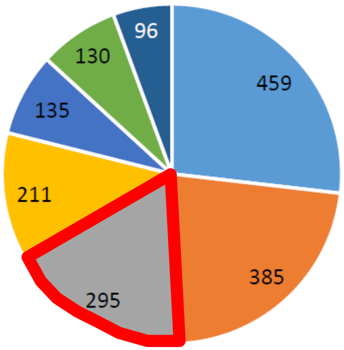
- “PLL loss of synch” tripping ≠ “Phase jump” tripping
  - No inverters tripped on PLL loss of synch
  - Phase jump protection is form of passive anti-islanding,
  - Misinterpreting phase angle shift during faults as islanding
  - Compares angle diff between inverter voltage and current phasors; operates for a change larger than 15 degrees within 500 ms.
  - NERC guidance specifically states that passive anti-islanding protection should be disabled for all BPS-connected inverter-based resources
  - This inverter OEM has been installing inverters across North America with this form of protection enabled at the vast majority of BPS-connected facilities. Poses a relatively significant risk to BPS reliability – likely to misoperate for normal BPS faults.

Inverter Phase Jump Protection



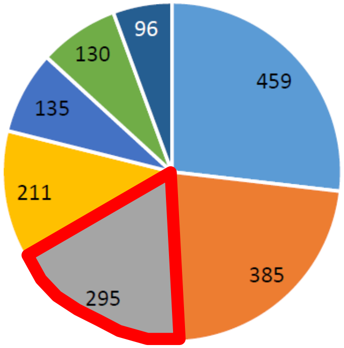
- NERC, Texas RE, and ERCOT strongly recommended this protection be disabled at all BPS-connected solar PV facilities.
  - ERCOT corroborated this statement with local TOs to ensure they do not rely on this form of protection in any way
  - TOs also strongly recommended that this protection be disabled so as to not cause inadvertent tripping
- The inverter OEM has stated they will be disabling the passive anti-islanding protection upon request from GOs and will likely be disabling the protection as a default for future installations
  - Increased trip threshold in cases where entities keep it enabled

Inverter Instantaneous AC Overvoltage



- Persistent, recurring cause of tripping for solar PV
- Overvoltage occurs at fault clearing
- Linked to inverter control strategy during and immediately following fault condition
  - Tripping set at 1.25 pu for 0.2 ms
- Inadequacies in PRC-024-3 to address this cause of tripping
  - Uses POI voltages; but no industry standard to translate POI voltages to inverter voltages during faults
  - Requires extensive EMT modeling and studies to identify risk

Inverter Instantaneous AC Overvoltage



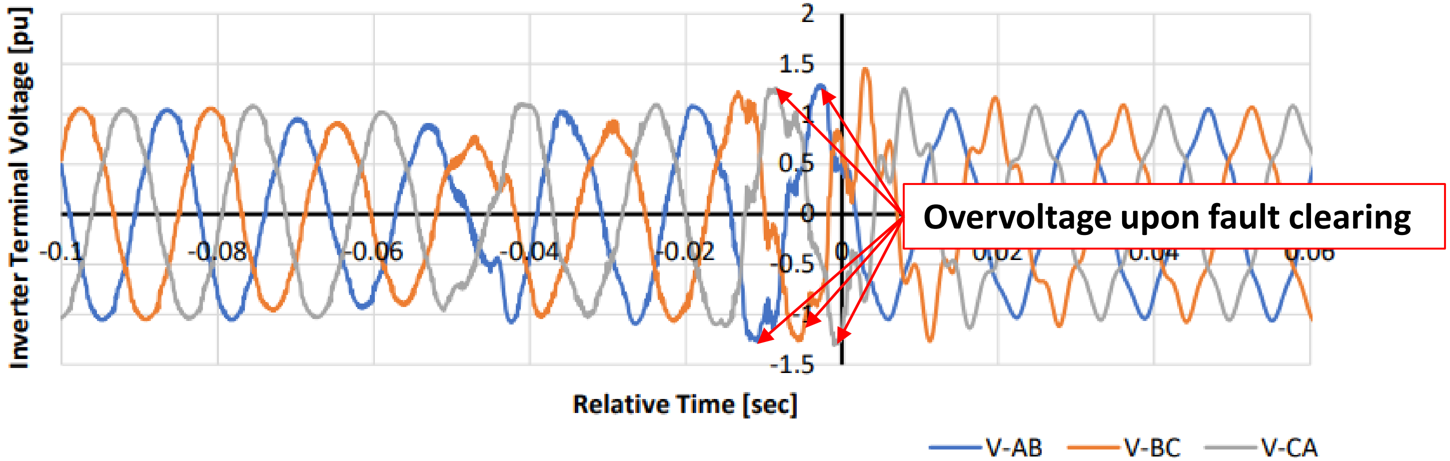


Figure 1.5: Inverter-Level High Speed Oscillography Voltage Data

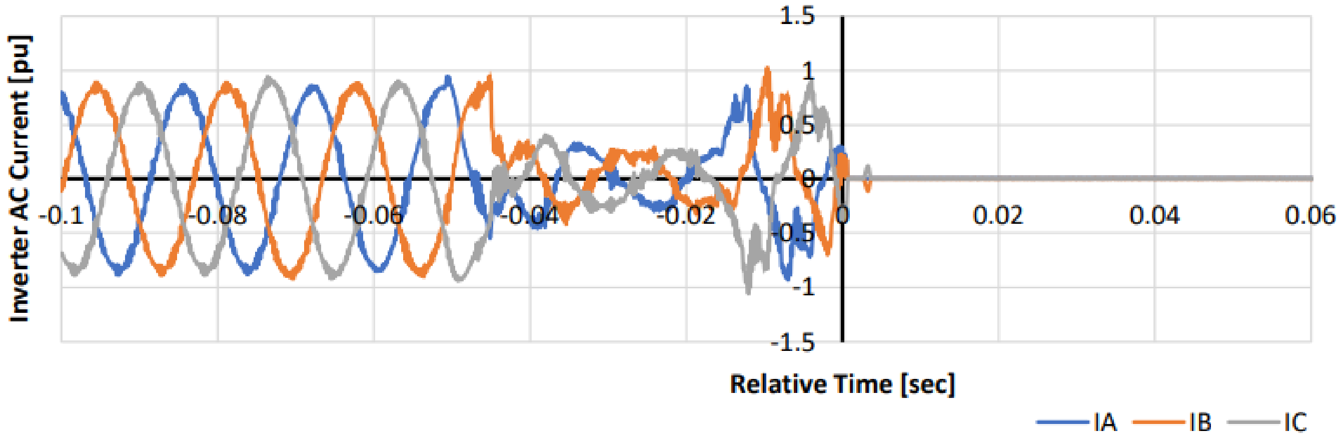
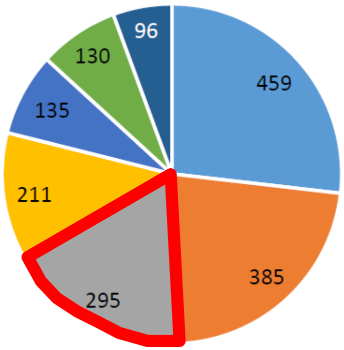
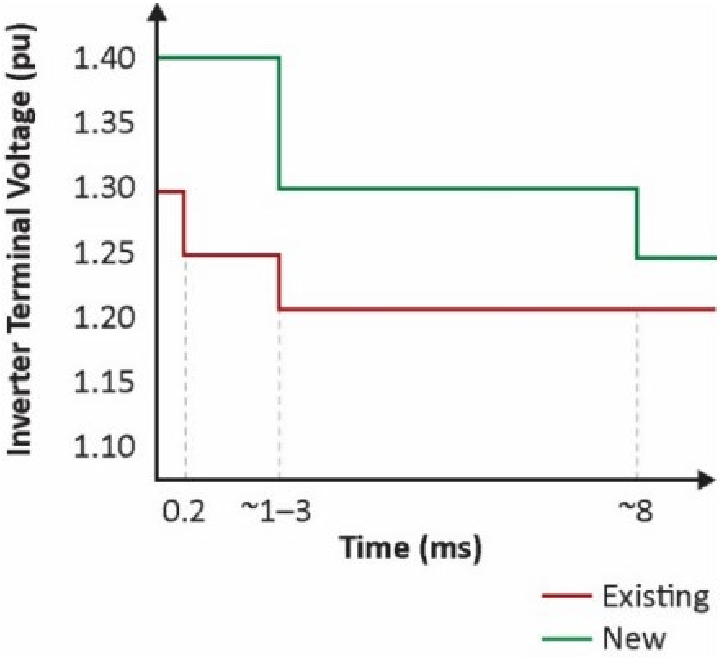


Figure 1.6: Inverter-Level High Speed Oscillography Current Data

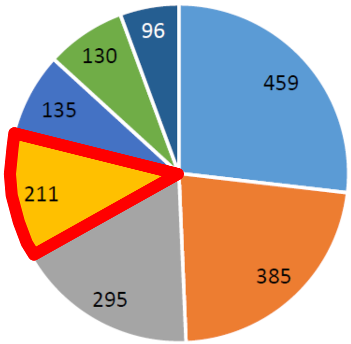
Inverter Instantaneous AC Overvoltage



- Inverter OEM updated inverter protection settings to extend ac overvoltage protection
  - Changes to user-settable and OEM-settable settings
  - Updates require inverter OEM technician on-site
  - Protections should match actual equipment capabilities

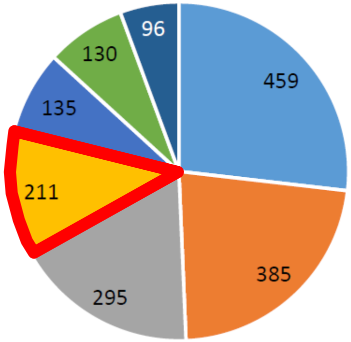


Inverter DC Voltage Imbalance



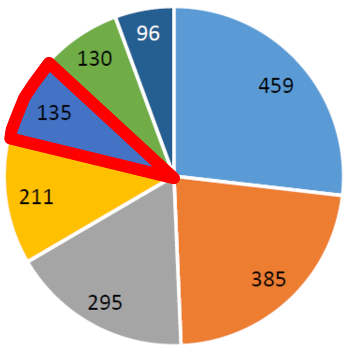
- Observed at three facilities, same OEM, different inverter models
  - Observed in California in 2021 for same types of inverters
- Occurs when voltage difference between positive and negative terminals on the inverter dc bus is measured (|V(P)–V(N)| > Threshold)
  - Unbalanced (negative sequence) voltage on ac side of inverter can cause a ripple on the dc bus that must be managed by inverter inner control loops
  - If inverter controls are not fast enough, dc-side ripple may surpass the trip threshold
- NERC and WECC identified that a firmware upgrade was available for existing solar PV facilities after the 2021 solar PV disturbances in California.

Inverter DC Voltage Imbalance



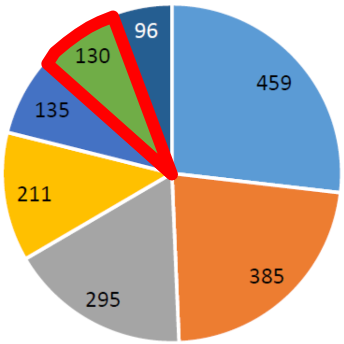
- Firmware upgrade reconfigures inner controls, enables faster control of inverter module currents
- Inverter OEM stated that upgrade will reduce tendency of inverters tripping if deployed
- Firmware upgrades not rolled out between 2021 and 2022
- Upgrades should be implemented immediately to mitigate any unnecessary inverter tripping
- Inverter OEM informed NERC, Texas RE, and ERCOT that they are rolling this update out fleet-wide for specific models of inverters with the Texas Interconnection being the top priority.

Incorrect Inverter Ride-Through Configuration



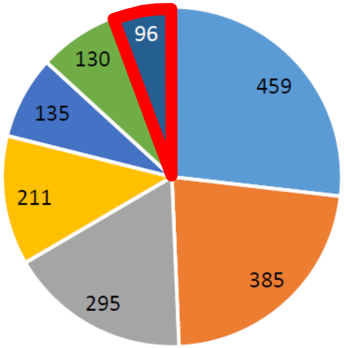
- One facility had all inverters misconfigured with low voltage ride through settings disabled.
  - Unable to provide active and reactive current/power during and immediately after fault events
- GO identified the misconfiguration during its investigation of the facility
- GO changed all inverters to a mode that allows for both active and reactive power injection during ride-through operation.

Inverter Momentary Cessation



- One facility had momentary cessation enabled
- GO disabled momentary cessation for all inverters based on 2019 NERC alert
- However, inverters are not equipped with uninterruptible power supplies; rely on momentary cessation during low voltage conditions to avoid tripping (hardware limitation).
- Design choice leads to poor performance and lack of essential reliability services; should not be allowed
    - Not a legitimate reason for the facility to not be able to provide dynamic reactive power support

Unknown



- Multiple solar PV facilities tripped for unknown reasons
- Attributed to issues including:
  - Inverter firmware issues
  - Inverter logs being overwritten
- No systemic causes of lack of data or information in this event
  - Majority of facilities have legacy KACO inverters (now out of business)

Additional Tripping: Feeder Underfrequency Protection

- Operated in addition to inverter-level tripping
- Trip settings of 57.5 Hz with an instantaneous (0.0 sec) timer
  - Instantaneously measured frequency was primary contributor to Blue Cut Fire event in 2016
  - NERC subsequently issued multiple guidelines and an alert with strong recommendations to eliminate its use
  - PRC-024-2 was modified to clarify this issue as well
  - Clear industry is not adhering to recommendations or clarifications set forth in guidelines, alert, or modifications to the standard
  - Further strengthens the need for a performance-based comprehensive ride-through standard to replace the existing PRC-024-3
- Protections not set based on equipment ratings; rather, configured (usually by consultants) to simply meet requirements in standards (no technical basis for their use)

ERCOT Risk Mitigation Activities in 2022

- Conducted meetings with GOs, OEMs, Texas RE, and NERC to investigate root causes for inverter tripping and potential corrective actions
- Required affected GOs to submit mitigation plan and timeline to correct issues
  - NOG Section 2.9.1 (8): *If an IRR fails to comply with the clearing time or recovery VRT requirement, then the IRR and the interconnecting TSP shall be required to investigate and report to ERCOT on the cause of the IRR trip, identifying a reasonable mitigation plan and timeline.*
- Followed up continuously with GOs and OEMs to check mitigation plan progress
  - Most facilities have completed implementing corrective actions (Table 2.2 in NERC *2022 Odessa Disturbance* Report)
  - TMEIC has yet to approve software update to mitigate AC overcurrent issue

Table ES.2: Effect of Proposed Mitigations

Plant Type	Reduction [MW]	Mitigated Reductions [MW]*
Solar PV Plants	1,711	1,633

* Assumes the mitigations stop unexpected or abnormal reductions during ride-through events and that these actions are implemented on-site. Does not include potential additional underlying ride through deficiencies.

ERCOT Risk Mitigation Activities in 2022

- Drafted Nodal Operating Guide Revision Request (NOGRR) to improve VRT and FRT requirements in accordance with IEEE 2800 Standard
- From Odessa 2021 event:
  - Verified with all operational plants with TMEIC inverters that PLL Loss of Synchronism function has been disabled
  - Continued efforts to prevent feeder breaker/ inverter tripping due to instantaneous underfrequency measured during fault conditions
  - Developed tools and procedures to look for smaller events where system fault results in loss of IBR/inverter tripping
  - Created Inverter Based Resource Task Force (IBRTF) – Open and closed sessions that meet monthly

ERCOT Risk Mitigation Activities Planned for 2023

- Send out formal requests in January to GOs of affected facilities that models will need to updated and resubmitted
  - *Per ERCOT Planning Guides: GOs are required to submit a Verification Report, updated dynamic model, and model quality test reports within 30 days of implementing a settings change or after observing a model update is needed to accurately represent the facility.*
- Reach out to all facilities (Operational or Commissioning) with TMEIC, Power Electronics, or KACO inverters
  - TMEIC: Extending VRT settings, Volt Phase Jump adjustment/disabling, overcurrent mitigation (Will not be adjusting DVC k-factor for additional facilities at this time)
  - Power Electronics: Implement DC regulation firmware update; check that correct LVRT/OVRT mode is enabled
  - KACO: Check that VRT and FRT settings are set to actual equipment tolerances and not loosely based on NOG and PRC ride-through curves

ERCOT Risk Mitigation Activities Planned for 2023

- Improve data requirements in NOG for PMU and DME (DFR, DDR, relay event data, etc.)
- Continue process for implementing new VRT and FRT language in NOGRR
- Improve Interconnection Process to check for known issues during Commissioning and improving model accuracy
- Automate tools to search for smaller events
- Continue to develop and implement process for corrective actions and update models from abnormal IBR performance discovered in future events
- Run system-wide validation study on updated models

Modeling and Studies

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Positive Sequence vs. EMT Modeling Capabilities

Can the models recreate the cause of reduction?

Table 3.1: Solar PV Tripping and Modeling Capabilities and Practices

Cause of Reduction	Can Be Accurately Modeled in Positive Sequence Simulations?	Can Be Accurately Modeled in EMT Simulations?
Inverter Instantaneous AC Overcurrent	No	Yes
Passive Anti-Islanding (Phase Jump)	Yes[a]	Yes
Inverter Instantaneous AC Overvoltage	No	Yes
Inverter DC Bus Voltage Unbalance	No	Yes
Feeder Underfrequency	No[b]	No[c]
Incorrect Ride-Through Configuration	Yes	Yes
Plant Controller Interactions	Yes[d]	Yes[e]
Momentary Cessation	Yes	Yes
Inverter Overfrequency	No[b]	Yes
PLL Loss of Synchronism	No	Yes
Feeder AC Overvoltage	Yes[f]	Yes
Inverter Underfrequency	No[b]	Yes

Positive Sequence vs. EMT Modeling Capabilities

Do the models recreate the cause of reduction?

Table 3.4: Review of Solar PV Facilities

Facility ID	Reduction [MW]	Cause of Reduction	Positive Sequence Model Capable?	EMT Model Capable?
Plant B	133	Inverter phase jump (passive anti-islanding) tripping.	Unknown*	Unknown
Plant C	56	Inverter phase jump (passive anti-islanding) tripping.	Unknown	Unknown
Plant E	159	Inverter ac overvoltage tripping.	Unknown*	Unknown
Plant U	136	Inverter ac overvoltage tripping; feeder underfrequency tripping.	Unknown	Unknown
Plant F	46	Unknown.	Unknown	Unknown
Plant I	196	Inverter phase jump (passive anti-islanding) tripping.	Unknown	Unknown
Plant J	106	Inverter dc voltage imbalance tripping.	Unknown	Unknown
Plants K + L	130	Momentary cessation/inverter power supply failure.	Unknown	Unknown
Plant M	146	Inverter dc voltage imbalance tripping; incorrect inverter ride through configuration.	Unknown	Unknown
Plant N	35	Unknown.	Unknown	Unknown
Plant O	15	Unknown.	Unknown	Unknown
Plant P	10	Inverter ac overcurrent tripping.	Unknown*	Unknown
Plant Q	12	Inverter ac overcurrent tripping.	Unknown	Unknown
Plant R	261	Inverter ac overcurrent tripping.	Unknown*	Unknown
Plant S	94	Inverter dc voltage imbalance tripping.	Unknown*	Unknown
Plant T	176	Inverter ac overcurrent tripping; feeder underfrequency tripping.	Unknown*	Unknown

Positive Sequence vs. EMT Modeling Capabilities

- Modeling practices today omit many protections (e.g., ac overcurrent, dc bus protection, balance of plant)
  - DC-side bus protections not often modeled
    - Technically feasible but not currently explicitly required
  - Feeder-level protection not always modeled
    - Equipment manufacturer verified EMT and Positive Sequence models are not always available
- Models submitted are not representative of the facility
  - Models are not parameterized to match facility performance
  - Model types or versions may not be sufficiently accurate to represent inverters
  - No comparisons between positive sequence, EMT, and real inverters to ensure accuracy and fidelity of models

Inverter Manufacturer Feedback on Modeling Capabilities

- Inability of positive sequence simulations to capture potential causes of tripping
  - Cannot capture instantaneous quantities/protections
  - Do not represent complicated PLL logic
  - Do not represent the dc bus
- Strongly recommend using user-defined models
  - Standard library models generally inadequate
  - Significant limitations to represent OEM inverter controls
- Mixed EMT modeling capabilities
- Strongly recommend strengthened modeling requirements
  - Both EMT and positive sequence
  - Bring clarity and consistency to modeling expectations
  - Provide OEM justification to drive model improvements

ERCOT Model Quality and Validation Process

- ERCOT utilizes their Model Quality Test procedure to produce evidence of the performance of the model submitted into the interconnection process
  - ERCOT stated that their model quality test are intended to demonstrate reasonable **model** performance when compared to ERCOT performance requirements
  - This creates a process that does not prioritize the accuracy and fidelity of the model when compared to the facility
  - The primary focus on the model performance creates incentive to simply curve fit any model to meet ERCOT requirements without considering if that performance is possible or configured at each facility
  - Additional mapping and information should be required if the parameters in the model and facility are not identical

ERCOT Model Quality and Validation Process

- ERCOT requires generator owners submit a parameter verification report to compare model parameters to installed parameters
  - More detail is need to ensure all parameters that effect performance are addressed
- Models should be verified by the equipment manufacturer with confirmation that the performance and parameters in the models submitted are accurate representations of the facility
- ERCOT should report any facility with inaccurate models to NERC and Regional Entity Compliance Assurance teams

Commissioning Process Enhancements Needed

- OEMs lose visibility during interconnection process
- Once models are provided to developer/GO, final models that include tuned parameters or enabled features are not incorporated into commissioning
  - Representation of facility used in studies does not match actual controls/protections of the commissioned facility
  - Representation used in studies may contain performance that is physically impossible for the inverter
  - Leads to inaccuracies in models and possible unreliable performance of inverter-based resource fleet

Key Modeling Takeaways

- EMT modeling requirements are critical moving forward
  - Modeling requirements will drive model improvements
- EMT model quality checks are necessary for model accuracy
  - Positive sequence benchmarking against EMT is necessary
- Model parameterization needs to match reality
  - Explicit verification of commissioned parameters against those studied during the interconnection process
- Forms of protections and controls that can trip the facility should be represented in models (ride-through studies)
  - These functions should also be tested for functionality and accuracy
  - Includes inverter **and** balance of plant protections

Key Modeling Takeaways

- Positive sequence models unable to ensure plant ride-through performance before real-time operations
- Strong and growing need for EMT modeling/studies moving forward
  - EMT models should be used for detailed and accurate ride through studies and for benchmarking of positive sequence models
- Changes to facilities require studies and approval by TP/PC *before* being made
  - Consider any change to electrical behavior (steady-state or dynamic) a "qualified change" per NERC FAC-002-4

Conclusions and Closing Remarks

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Conclusion

- Elevating the inverter risk issues within the ERO risk framework
- Immediate action by industry stakeholders to enhance local interconnection requirements
- Agile NERC Standards development activities
  - Comprehensive ride-through standard
  - New performance validation standard
  - Disturbance monitoring, EMT, planning assessments, etc.
- Level 2 NERC Alert(s) to understand extent of condition
  - Performance issues and modeling issues
- Enhancements to the FERC *pro forma* GIAs
- Improvements to plant commissioning practices
- FERC NOPR on inverter-based resources

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NERC IBR Strategy

Risk Analysis	Interconnection Process Improvements	Best Practices and Education	Regulatory Enhancements
Event Analysis	Improvements to GIAs and GIP	Reliability Guidelines	NERC Standards Projects
Disturbance Reports	Enhanced Interconnection Requirements	Webinars and Workshops	BES Definition Review
Alerts	Modeling and Study Improvements	Outreach and Engagement	Inverter-Specific Requirements and Standards
Lessons Learned	IEEE 2800-2022	Emerging Reliability Risk Issues	Risk-Based Compliance

Questions and Answers

Feel free to reach out to us if interested in participating in the NERC IRPS!
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